

PATENT  
8733.904.00

**UNITED STATES PATENT APPLICATION**

**OF**

**DON GYOU LEE**

**KI YON SONG**

**AND**

**JUNG HO KIL**

**FOR**

**LIQUID CRYSTAL DISPLAY DEVICE AND METHOD FOR IMPROVING COLOR  
REPRODUCIBILITY THEREOF**

**MCKENNA LONG & ALDRIDGE LLP  
1900 K STREET, N.W.  
WASHINGTON, D.C. 20006  
Tel: (202) 496-7500  
Fax: (202) 496-7756**

[0001] This application claims the benefit of the Korean Application No. P2002-88455 filed on December 31, 2002, which is hereby incorporated by reference for all purposes as if fully set forth herein.

## **BACKGROUND OF THE INVENTION**

### **Field of the Invention**

[0002] The present invention relates to liquid crystal display (LCD) devices and a method for improving color reproducibility thereof, and more particularly to an LCD device and a method for improving a color reproducibility of an LCD device, wherein colors are displayable by the LCD panel by mixing red, green, and blue colors displayable at multiple gray scale levels.

### **Discussion of the Related Art**

[0003] Flat thin film-type displays express color images, are lightweight, and portable display devices. Liquid crystal display (LCD) devices in particular are capable of displaying pictures at high resolutions, have fast response speeds, and are therefore capable of displaying of moving pictures. Accordingly, research on the design and manufacture of LCD devices is actively performed.

[0004] Color LCD devices operate according to anisotropic optical characteristics and polarization properties of liquid crystal molecules. More specifically, alignment directions of liquid crystal molecules with anisotropic optical characteristics can be manipulated to selectively transmit light. Active matrix LCD (AM-LCD) devices display pictures at a high quality and are formed using thin film transistors (TFTs) connected to pixel electrodes

arranged in a matrix pattern. A structure of general LCD device will now be described in greater detail.

[0005] A related art LCD device generally includes an LCD panel having a color filter panel and an opposing TFT array panel both formed of transparent substrate material. The color filter and TFT array panels are disposed a predetermined distance from each other to define a cell gap. A layer of liquid crystal material is formed within the cell gap. The color filter panel supports red, green, and blue color filters sequentially arranged at positions corresponding to the pixel electrodes, a black matrix having a net-type shape formed between the color filters, and a common electrode formed on the color filters. The TFT array panel supports pixel electrodes arranged at pixel positions provided in a matrix pattern, gate lines formed along a horizontal direction of the pixel electrodes, data lines formed along a vertical direction of the pixel electrodes, and TFTs for driving the pixel electrodes formed at sides of the pixel electrodes. Each TFT includes a gate electrode connected to the corresponding gate line and a source electrode connected to the corresponding data line. Moreover, pad units, formed at ends of the gate and data lines, are used to connect the TFTs to external driving circuits.

[0006] Figure 1 illustrates a schematic view of a related art liquid crystal display panel and a related art driving unit.

[0007] Referring to Figure 1, red (R), green (G), and blue (B) image information (DATA) and control signals (CS) are applied to a timing control unit 120 via an interface unit 110. A system power (VCC) is applied to the timing control unit 120 and a power unit 130.

[0008] The timing control unit 120 applies the control signal (CS) to a gate driving unit 140 and applies the image information (DATA) and the control signal (CS) to a data driving

unit 150. The control signal (CS) includes a clock signal, a gate start signal, and a timing signal and enables the timing control unit 120 to control a driving timing of the gate and data driving units 140 and 150.

[0009] The power unit 130 receives the system power (VCC), applies gate on/off power ( $V_{G-ON}$ ,  $V_{G-OFF}$ ) to the gate driving unit 140, applies a reference voltage ( $V_{REF}$ ) to the data driving unit 150, and applies a common voltage ( $V_{COM}$ ) to the common electrode of the LCD panel 100.

[0010] The gate driving unit 140 receives the control signal (CS) applied by the timing control unit 120 and the gate on/off power ( $V_{G-ON}$ ,  $V_{G-OFF}$ ) applied by the power unit 130 and applies scan signals to the gate lines of the LCD panel 100.

[0011] The data driving unit 150 receives the control signal (CS) and the image information (DATA) applied by the timing control unit 120 and the reference voltage ( $V_{REF}$ ) applied by the power unit 130 and applies the image information (DATA) to the data lines of the LCD panel 100.

[0012] Pixels in the LCD panel 100 are arranged in a matrix pattern and express light of predetermined colors in accordance with the applied image information (DATA), applied by the data driving unit 150 in accordance with the scan signals applied by the gate driving unit 140. R, G, and B image information (DATA) are applied to corresponding ones of R, G, and B pixels, wherein R, G, and B pixels constitute one dot within a display area of LCD panel 100. By combining light expressed by the R, G, and B pixels, predetermined colors may be displayed by the LCD panel 100.

[0013] To display natural-type colors, R, G, and B colors must be expressed by the LCD panel 100 at multiple gray scale levels. For example, when R, G, and B colors (i.e., the

three primary colors primary colors) are expressed by the LCD panel 100 without using gray scale levels, only  $2^3$  (i.e., 8) colors (black, red, green, blue, white, red + green, green + blue, and blue + red) are expressable by a dot of the LCD panel 100. However, when R, G, and B colors are expressed by the LCD panel 100 at an 8-bit gray scale level,  $2^{24}$  (i.e., 16,777,216) colors are  
5 expressable by a dot of the LCD panel 100. Accordingly, R, G, and B colors expressable using multiple gray scale levels can be mixed together to generate natural colors.

[0014] Figure 2 illustrates an X-Y chromaticity diagram, quantitatively illustrating natural colors.

[0015] Referring to Figure 2, the color and degree of color saturation can be uniquely  
10 described according to the X-Y coordinates of the chromaticity diagram. Light having chromatic values on and within the closed, horseshoe-shaped region C-100 is viewable by humans. Light having chromatic values within the triangular region T-100 defined by "R," "G," and "B" vertices is displayable using an NTSC fluorescent lamp. Accordingly, light within the triangular region T-100 may express color that is reproducible. Light having  
15 chromatic values defined by the R1, G1, and B1 distributions are expressed as red, green, and blue colors, respectively, and are displayable by the LCD panel 100 at multiple gray scale levels.

[0016] More specifically, when the gray scale level of light having a red color displayed by the related art LCD device is increased, in the chromaticity diagram, the R1  
20 distribution is generated. When the gray scale level of light having a green color displayed by the related art LCD device is increased, in the chromaticity diagram, the G1 distribution is generated. When the gray scale level of light having a blue color displayed by the related art LCD device is increased, in the chromaticity diagram, the B1 distribution is generated.

[0017] As the gray scale level of the blue color displayed by the related art LCD device increases, the end portion of the B1 distribution deviates along the Y-axis, away from the "B" vertex of the color reproduction region T-100. Accordingly, as the gray scale level of light having a blue color displayed by the related art LCD device increases, the degree to which the blue color is reproducible decreases. The phenomenon by which the color reproducibility is decreased upon increasing the gray scale level of light having the blue color will now be described in greater detail below.

[0018] Figure 3 illustrates a graph of a Gooch-Tarry curve, indicating a difference in transmissivity of R, G, and B colors through the cell gap of the LCD device.

[0019] R, G, B colors have different wavelengths within a visible wavelength region. Similarly, and with reference to Figure 3, R, G, and B colors are transmitted by the LCD device according to the cell gap and a refractive index of the liquid crystal material provided within the cell gap. Accordingly, distortion of colors expressed by the LCD device may occur. For example, transmissivity characteristics of light having blue color are reduced when transmitted through a normal cell gap. Accordingly, the gray scale level of the blue color must be increased. However, as the gray scale level of the blue color increases, the end of the B1 distribution undesirably deviates along the Y-axis, away from the "B" vertex of the color reproduction region T-100 shown in Figure 2.

[0020] Therefore, within the related art LCD device, color reproducibility of light having blue color decreases as the gray scale level of the blue color displayed by the related art LCD device increases. Due to the aforementioned transmissivity and reproducibility characteristics of light having the blue color, the quality with which the LCD device displays pictures is lowered and the overall desirability of the LCD device may be reduced.

### **SUMMARY OF THE INVENTION**

[0021] Accordingly, the present invention is directed to a liquid crystal display device and a method for improving color reproducibility thereof that substantially obviates one or more of the problems due to limitations and disadvantages of the related art.

[0022] An advantage of the present invention provides an LCD device and a method for improving a color reproducibility of an LCD device and for facilitating of the display of colors by mixing red, green, and blue colors at multiple gray scale levels.

[0023] Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. These and other advantages of the invention will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

[0024] To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, a liquid crystal display device may, for example, include a liquid crystal display panel having gate lines and data lines, wherein the gate lines cross the data lines, and wherein R, G, and B pixels are arranged in a matrix pattern defined by crossings of the gate and data lines; a gate driving unit for applying scan signals to the gate lines; a lookup table for storing a gray scale value corresponding to a maximum gray scale level of light having a color displayable by the liquid crystal display panel prior to a reduction in a color reproducibility of the color, wherein the color is displayable at multiple gray scale levels, and wherein the color includes at least one of a red (R), green (G), and blue (B) color; a data processing unit for compensating image information according to the gray

scale value stored by the lookup table; and a data driving unit for receiving the compensated image information and for applying the compensated image information to the data lines of the liquid crystal display panel.

[0025] In accordance with the principles of another aspect of the present invention, a method for improving a color reproducibility of a color liquid crystal display device may, for example, include detecting a gray scale value at which a color reproducibility of light displayable by a liquid crystal display panel is decreased, wherein the detecting includes measuring a gray scale level of color displayed on the liquid crystal display panel while increasing a gray scale value of at least one of R, G, B colors displayed on the liquid crystal display panel; storing the gray scale value immediately preceding the decreasing of the color reproducibility; compensating image information using the stored gray scale value; and applying the compensated image information to data lines of the liquid crystal display panel.

[0026] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0027] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

[0028] In the drawings:



[0029] Figure 1 illustrates a schematic view of a related art liquid crystal display panel and a related art driving unit;

[0030] Figure 2 illustrates an X-Y chromaticity diagram, quantitatively illustrating natural colors;

5 [0031] Figure 3 illustrates a graph of a Gooch-Tarry curve, indicating a difference in transmissivity of R, G, and B colors through the cell gap of the LCD device;

[0032] Figure 4 illustrates a schematic view of an LCD panel and driving unit in accordance with principles of a first aspect of the present invention;

10 [0033] Figure 5 illustrates a method for improving a color reproducibility of an LCD device in accordance with principles of a first aspect of the present invention;

[0034] Figure 6 illustrates an exemplary lookup table relating gray scale levels of blue colors having 64-bit gray scale levels, displayable by a liquid crystal display panel, to corresponding gray scale values;

15 [0035] Figure 7 illustrates a graph of increases in a gray scale level of light having a blue color, displayable by a liquid crystal display panel, according to gray scale values stored in the lookup table shown in Figure 6;

[0036] Figure 8 illustrates an exemplary lookup table relating gray scale levels of R, G, and B colors, displayable by a liquid crystal display panel, to corresponding gray scale values; and

20 [0037] Figure 9 illustrates a graph of increases in a gray scale level of light having a blue color, displayable by a liquid crystal display panel, according to gray scale values stored in the lookup table shown in Figure 8.

## **DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS**

[0038] Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

[0039] Figure 4 illustrates a schematic view of an LCD panel and driving unit in accordance with principles of a first aspect of the present invention. Figure 5 illustrates a method for improving a color reproducibility of an LCD device in accordance with principles of a first aspect of the present invention.

[0040] Referring to Figures 4 and 5, R, G, and B image information (DATA) and control signals (CS) may be applied to a timing control unit 220 via an interface unit 210. A system power (VCC) may be applied to the timing control unit 220 and a power unit 230.

[0041] The timing control unit 220 may apply the control signal (CS) to a gate driving unit 240 and a data driving unit 250. Further, the timing control unit 220 may apply the image information (DATA) to a data processing unit 270. In one aspect of the present invention, the control signal (CS) may include a clock signal, a gate start signal, and a timing signal and may control a driving timing of the gate and data driving units 240 and 250, respectively.

[0042] The power unit 230 may receive the system power (VCC) and apply a gate on/off power ( $V_{G-ON}$ ,  $V_{G-OFF}$ ) to the gate driving unit 240, apply a reference voltage ( $V_{REF}$ ) to the data driving unit 250, and apply a common voltage ( $V_{COM}$ ) to a common electrode of a liquid crystal display (LCD) panel 200.

[0043] In one aspect of the present invention, the gate driving unit 240 may receive the control signal (CS) applied by the timing control unit 220 and the gate on/off power ( $V_{G-ON}$ ,  $V_{G-OFF}$ ) applied by the power unit 230. Further, the gate driving unit 240 may sequentially apply scan signals to the gate lines of the liquid crystal display panel 200.

[0044] In accordance with the principles of the present invention, a blue color having 64-bit gray scale levels may be displayable by the LCD panel 200. In one aspect of the present invention, the gray scale level of the blue color displayable by the LCD panel 200 may be increased from a 1<sup>st</sup> bit gray scale level to a 64<sup>th</sup> bit gray scale level. By increasing a gray scale value of the blue color displayed by the LCD panel 200, the gray scale level of the blue color displayed by the LCD panel 200 may be increased. Further, upon increasing the gray scale value of the blue color displayed by the LCD panel 200, the color reproducibility of the displayed blue color may be measured. Accordingly, the gray scale value at which the color reproducibility of the displayed blue color decreases may be detected using a lookup table 260.

10 [0045] For example, light having a blue color may be displayable by the LCD panel 200 at 64-bit gray scale levels. Moreover, color reproducibility of light displayed by the LCD panel 200 may be measured while increasing the gray scale value.

[0046] Referring to Figure 6, color reproducibility of blue colored light may decrease when the gray scale level of the displayed blue color increases to the 52<sup>nd</sup> bit gray scale level. According to the lookup table 260, blue color is displayable by the LCD panel 200 at the 51<sup>st</sup> bit gray scale level immediately before it is displayable by the LCD panel 200 at the 52<sup>nd</sup> bit gray scale level. Therefore, blue color may be displayed by the LCD panel 200 at the 51<sup>st</sup> bit gray scale level immediately before the reproducibility of the displayed blue color decreases. Within the lookup table 260, a gray scale value of 50 corresponds to the 52<sup>nd</sup> bit gray scale level displayable by the LCD panel 200 (e.g., the displayed gray scale level where color reproducibility of the blue color is lowered) up to the 64<sup>th</sup> bit gray scale level displayable by the LCD panel 200 (e.g., the highest gray scale level).

[0047] According to the principles of the present invention, the data processing unit 270 may compensate image information (DATA) applied by the timing control unit 220 in accordance with the gray scale values stored in the lookup table 260. For example, when the received image information (DATA) corresponds to a blue color displayable by the LCD panel 200 at a gray scale level greater than the 52<sup>nd</sup> bit gray scale level, the data processing unit 270 may compensate the gray scale value within the image information (DATA) in accordance with the gray scale value and levels stored in the lookup table 260. Accordingly, the data processing unit 270 may compensate the image information (DATA) such that a blue color may be displayed by the LCD panel 200 at a gray scale level equal to the 51<sup>st</sup> bit gray scale level. Therefore, the image information may be compensated to include a gray scale value corresponding to the 51<sup>st</sup> bit gray scale level. In one aspect of the present invention, the compensated image information (DATA) and the reference voltage ( $V_{REF}$ ) may be applied by the data processing unit 270 and the power unit 230, respectively, to the data driving unit 250. In accordance with the control signal (CS) applied from the timing control unit 220, the driving timing of the gate and data driving units 240 and 250, respectively, may be controlled. As a result, the compensated image information (DATA) may be applied to the data lines of the LCD panel 200.

[0048] According to the principles of the first aspect of the present invention, gray scale values within image information can be compensated by detecting the increased blue color gray scale level accompanying a decrease in color reproducibility. The decrease in color reproducibility may be determined by measuring the gray scale level of the color displayed by the LCD panel. Upon measuring the decrease in color reproducibility, corresponding gray

scale values within the image information may be stored such that the gray scale value applied immediately prior to the decrease in color reproducibility may be determined.

[0049] Figure 7 illustrates a graph of increases in a gray scale level of light having a blue color, displayable by a liquid crystal display panel, according to gray scale values stored in the lookup table shown in Figure 6

[0050] Referring to Figure 7, upon increasing the gray scale level of the blue color displayable by the LCD panel 200 in accordance with an increase in a gray scale value, a distribution shown at B11 may be obtained. As shown in the Figure, the Y-axis distortion discussed above with reference to the end portion of the B1 distribution of Figure 2 may be substantially prevented. Accordingly, the principles of the present invention may substantially prevent the color reproducibility from being decreased.

[0051] Figure 8 illustrates an exemplary lookup table relating gray scale levels of R, G, and B colors, displayable by a liquid crystal display panel, to corresponding gray scale values.

[0052] Referring to Figure 8, a blue color having 64-bit gray scale levels may be displayable by an LCD panel. In one aspect of the present invention, the gray scale level of the blue color displayable by the LCD panel 200 may be increased from a 1<sup>st</sup> bit gray scale level to a 64<sup>th</sup> bit gray scale level. By increasing the gray scale value of the blue color, the gray scale level of the blue color displayed by the LCD panel 200 may be increased. Further, upon increasing the gray scale value of the blue color displayed by the LCD panel, the color reproducibility of the displayed blue color may be measured. Accordingly, the gray scale value at which the color reproducibility decreases may be detected using a lookup table 360. According to the lookup table 360, the blue color is displayable by the LCD panel at the 51<sup>st</sup> bit gray scale level immediately before it is displayable by the LCD panel 200 at the 52<sup>nd</sup> bit gray

scale level. Accordingly, blue color may be displayed by the LCD panel at the 51<sup>st</sup> bit gray scale level immediately before the reproducibility of the displayed blue color decreases.

Within the lookup table 360, a gray scale value of 50 corresponds to the 52<sup>nd</sup> bit gray scale level displayable by the LCD panel 200 (e.g., the color reproducibility of the blue color is lowered)

5 up to the 64<sup>th</sup> bit gray scale level displayable by the LCD panel (e.g., the highest gray scale level).

[0053] Additionally, light having a green color may be displayed by the LCD panel at gray scale levels of 1,1,2,2,3,3,4,4,5,5,6,6, and 7. Moreover, light having a red color may be displayed by the LCD panel at gray scale levels of 1,1,2,2,3,3,4,4,5,5,6, and 6. In one aspect

10 of the present invention, the gray scale levels of the green and red colors may be mixed with corresponding ones of the 52<sup>nd</sup> to 64<sup>th</sup> bit gray scale levels of the blue color. For example, when the received image information (DATA) corresponds to a blue color displayable by the

LCD panel 200 at a gray scale level greater than the 52<sup>nd</sup> bit gray scale level, light having a green color may be displayed by the LCD panel at gray scale levels of 1,1,2,2,3,3,4,4,5,5,6,6,

15 or 7 and/or light having a red color may be displayed by the LCD panel at gray scale levels of 1,1,2,2,3,3,4,4,5,5,6, or 6 may be mixed with the received image information to ensure reproducibility of the blue color displayable by the LCD panel.

[0054] According to the principles of the second aspect of the present invention, color reproducibility of light displayed by LCD panels may be measured as the gray scale level of the

20 displayed light is increased. Accordingly, a gray scale value within the image information (DATA), corresponding to a gray scale level displayed by the LCD panel immediately before the color reproducibility is reduced, may be determined. Within the lookup table 360, a gray scale value of 50 corresponds to the 52<sup>nd</sup> bit gray scale level displayable by the LCD panel (e.g.,

the displayed gray scale level where color reproducibility of the blue color is lowered) up to the 64<sup>th</sup> bit gray scale level displayable by the LCD panel (e.g., the highest gray scale level).

[0055] Referring to Figure 9, upon mixing gray scale levels of red and green colors, and upon increasing the gray scale level of the blue color displayable by the LCD panel in accordance with an increase in a gray scale value, a distribution shown at B21 may be obtained. As shown in the Figure, the Y-axis distortion discussed above with reference to the end portion of the B1 distribution of Figure 2 may be substantially prevented. Further, according to the principles of the present invention, the end portion of the B21 distribution shown in Figure 9 is closer to the "B" vertex of the color reproduction region (T-100) of the NTSC fluorescent lamp shown in Figure 2 than the end portion of the B11 distribution shown in Figure 7. Therefore, the degree to which color reproducibility may be improved according to the second aspect of the present invention may be improved compared to the degree to which color reproducibility may be improved according to the first aspect of the present invention.

[0056] As described above, color reproducibility of light displayed by LCD panels may be measured as the gray scale level of the displayed light is increased. Accordingly, a gray scale value within the image information (DATA), corresponding to a gray scale level displayable by the LCD panel immediately before a color reproducibility is decreased, may be determined. Further, the gray scale value corresponding to the maximum gray scale level displayed by the LCD panel at which the color reproducibility is not reduced, may be stored in a lookup table. Accordingly, image information, including a gray scale value corresponding to a gray scale level displayable by an LCD panel at which a color reproducibility is reduced, may be compensated such that color may be displayed by the LCD panel at a gray scale level equal to the maximum gray scale level. The principles of the present invention may be

applied to substantially prevent a reduction in color reproducibility caused by distortion of the Y-axis of the chromaticity diagram as the gray scale level of a blue color displayable by an LCD panel is increased. Moreover, a picture quality of an LCD device may be improved, and the overall desirability of the LCD device may be improved.

5           **[0057]** It will be apparent to those skilled in the art that various modifications and variation can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

10